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(54) Title: MANUFACTURE OF ELECTRON EMITTING SOURCE, THE ELECTRON EMITTING SOURCE AND FLUORESCENT DISPLAY DEVICE

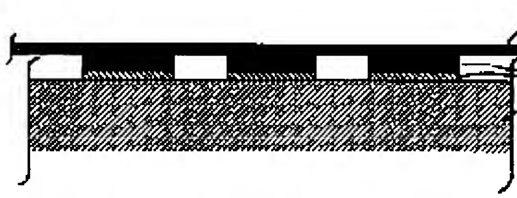
(57) Abstract

Task

To efficiently emit electrons with low-voltage drive by using a carbon material, having at least one of carbon nanotube, fullerene, nanoparticle, nanocapsule and carbon nanohorn.

Means for solution

A cathode conductor (102) and a paste-like carbon layer (201), including carbon nanotube, are laminated on an insulating substrate (101). A paper (301) is adhered to the carbon layer (201) and dried, so as to have the carbon layer (201) and the paper (301) unified. After peeling the surface part of the carbon layer (201) and the paper (301) from the carbon layer (201), the carbon layer (201) is burned to form an emitter. Thereafter, a gate electrode is formed so as to complete an electron emitting source.



CLAIMS

1. A method for the manufacture of an electron emission source by placing an emitter between a cathode conductor and a gate electrode then applying a voltage between the above cathode electrode and gate electrode to emit electrons from the emitter, characterized by involving a process of adhering a cathode electrode to an insulating substrate; a process of forming a carbon layer by coating the cathode electrode with a paste containing at least one of carbon nanotube, fullerene, nanoparticle, nanocapsule and carbon nanohorn; a process of adhering the paste form carbon layer with a porous sheet material and drying to integrate the carbon layer and the sheet; a process of forming an emitter by peeling the sheet material from the carbon layer then firing the carbon layer; and a process of forming a gate electrode at a position away from the emitter.

2. A method for the manufacture of an electron emission source by placing an emitter between a cathode conductor and a gate electrode then applying a voltage between the above cathode electrode and gate electrode to emit electrons from the emitter, characterized by involving a process of adhering a cathode electrode to an insulating substrate; a process of

adhering a resistance layer to the cathode conductor; a process of forming a carbon layer by coating the resistance layer with a paste containing at least one of carbon nanotube, fullerene, nanoparticle, nanocapsule and carbon nanohorn; a process of adhering the paste form carbon layer with a porous sheet material and drying to integrate the carbon layer and the sheet; a process of forming an emitter by peeling the sheet material from the carbon layer then firing the carbon layer; and a process of forming a gate electrode at a position away from the emitter.

3. The method for the manufacture of electron emission source according to Claim 1 or 2, characterized by the above porous sheet material being paper, fabric or ceramic sheet.

4. A method for the manufacture of an electron emission source by placing an emitter between a cathode conductor and a gate electrode then applying a voltage between the above cathode electrode and gate electrode to emit electrons from the emitter, characterized by involving a process of adhering a cathode electrode to an insulating substrate; a process of forming a carbon layer by coating the cathode electrode with a dispersion containing at least one of carbon nanotube, fullerene, nanoparticle, nanocapsule and carbon nanohorn; a process of drying the carbon layer; a process of forming an emitter by adhering an pressure-sensitive adhesive tape to the dried carbon layer then peeling the pressure-sensitive adhesive tape; and a process of forming a gate electrode at a position away from the emitter.

5. A method for the manufacture of an electron emission source by placing an emitter between a cathode conductor and a gate electrode then applying a voltage between the above cathode electrode and gate electrode to emit electrons from the emitter, characterized by involving a process of adhering a cathode electrode to an insulating substrate; a process of adhering a resistance layer to the cathode electrode; a process of forming a carbon layer by coating the resistance layer with a dispersion containing at least one of carbon nanotube, fullerene, nanoparticle, nanocapsule and carbon nanohorn; a process of drying the carbon layer; a process of forming an emitter by adhering a pressure-sensitive tape to the dried carbon layer then peeling the pressure-sensitive adhesive tape; and a process of forming a gate electrode at a position away from the emitter.

6. An electron emission source formed by placing an emitter between a cathode conductor and a gate electrode then applying a voltage between the above cathode electrode and gate electrode to emit electrons from the emitter, wherein the emitter is formed by coating the cathode electrode, directly or via a resistance layer, with a carbon material containing at least one of carbon nanotube, fullerene, nanoparticle, nanocapsule and carbon nanohorn, integrating the carbon material with a porous sheet material or a pressure-sensitive adhesive tape, followed by peeling the porous sheet material or the pressure-sensitive adhesive tape to remove the surface of the carbon material.

7. A fluorescent display device formed by placing an electron emission source and an anode electrode coated with a phosphor in a sealed vacuum container and colliding the electrons from the electron emission source with the phosphor to generate an emission display, characterized by using the electron emission source of Claim 6 as the electron emission source.

DETAILED EXPLANATION OF THE INVENTION

[0001]

TECHNOLOGICAL FIELD OF THE INVENTION

The present invention concerns a method for the manufacture of an electron emission source that emits electrons, an electron emission source prepared by such method and a fluorescent display device using the electron emission source.

[0002]

CONVENTIONAL TECHNOLOGY

Conventionally, electron emission sources formed by placing an emitter between a cathode conductor and a gate electrode (lead electrode) then applying a voltage between the above cathode electrode and gate electrode to emit electrons from the emitter are used in some applications and research of such sources have been in progress.

[0003]

The electric field electron emission source emitting electrons by the action of electric field is based on a phenomenon of emitting electrons in vacuum even at room temperature when an electric field of about 10^9 V/m is applied to the surface of metals, semiconductors, etc. with the electrons passing through barriers by the tunnel effect and has many excellent advantages such as low energy requirement, long life, etc. over the electron sources utilizing thermal energy (thermal electron emission source). The emitter materials are semiconductors such as silicon, etc., metals such as tungsten, molybdenum, etc., diamond-like carbon (DLC: diamond-like carbon), etc.

[0004]

Since the output current is determined by the field strength applied to the emitter, it is necessary to use emitter having a sharp tip for electron emission sources having high efficiency at low operating voltage. Thus, in the case of forming an emitter using the semiconductors and metals described above, it is necessary to fabricate the electron emission source tip into a sharp

needle form. However, fabricating tips of such semiconductors and metals into a sharp needle form is not easy and the necessity of large-scale apparatuses pushes up the cost.

[0005]

Recently, carbon nanotubes became of interest as the electron emission materials. The carbon nanotubes are extremely small fibrous carbon materials of 1 to several tens of mm in outer diameter, in shapes needed for easy field concentration and emission of electrons at low voltage, yet the carbon is characterized by having excellent chemical stability and mechanical toughness. Thus, they are suitable for emitters.

[0006]

For example, as described in Japanese Kokai Patent Application No. Hei 10[1998]-31954, an electron emission source using carbon nanotube is formed by printing a paste containing carbon nanotube on a cathode conductor or cathode conductor coated with a resistance layer, firing then installing rib gate electrode thereon, and electrons are emitted by applying a voltage between the cathode conductor and gate electrode.

[0007]

In the case of such electron emission source as the electron emission source for fluorescent display devices, an anode electrode coated with coated with a phosphor is installed facing against the electron emission source, and all are placed in a sealed vacuum container to form a fluorescent display device. With such constitution, by applying a certain positive voltage to the gate electrode and anode electrode, the phosphor is excited by the electron emitted from the carbon nanotube to generate the emission display.

[0008]

PROBLEMS TO BE SOLVED BY THE INVENTION

In the electron emission sources described in the above patent specification, a carbon material containing carbon nanotube is made into a paste, and the paste material is printed, dried and fired, thus the components in the solvents used for making the carbon material paste remains even after firing, and the emitters are formed with the carbon nanotube covered with such residue, resulting in increased work functions of the emitter. Thus, electron emission at low voltage is difficult, and often the carbon nanotube included in the emitter is hardened when laid in parallel to the insulating substrate, making the field concentration at the carbon nanotube tip difficult, electron emission at low voltage difficult and low electron emission efficiency.

[0009]

Beside the carbon nanotube, fullerene, nanoparticle, nanocapsule, carbon nanohorn, etc. are of interest as fine carbon materials. However, when emitters are made with pastes of these materials, the components in the solvents used for making the carbon material paste remains even after firing, and the emitters are formed with the carbon nanotube covered with such residue. Thus, emitting electrons efficiently at low voltage is difficult. Also, when the electron emission sources obtained by such methods are used for fluorescent display devices, obtaining displays of high brightness at low voltage is very difficult.

[0010]

Under such circumstances, the present invention is to make highly efficient electron emission at low operating voltage possible by using carbon materials containing at least one of carbon nanotube, fullerene, nanoparticle, nanocapsule, and carbon nanohorn.

[0011]

MEANS FOR SOLVING THE PROBLEMS

According to the present invention a method is provided for the manufacture of an electron emission source by placing an emitter between a cathode conductor and a gate electrode then applying a voltage between the above cathode electrode and gate electrode to emit electrons from the emitter, characterized by involving a process of adhering a cathode electrode to an insulating substrate; a process of forming a carbon layer by coating the cathode electrode with a paste containing at least one of carbon nanotube, fullerene, nanoparticle, nanocapsule and carbon nanohorn; a process of adhering the paste form carbon layer with a porous sheet material and drying to integrate the carbon layer and the sheet; a process of forming an emitter by peeling the sheet material from the carbon layer then firing the carbon layer; and a process of forming a gate electrode at a position away from the emitter.

[0012]

Also, according to the present invention a method is provided for the manufacture of an electron emission source by placing an emitter between a cathode conductor and a gate electrode then applying a voltage between the above cathode electrode and gate electrode to emit electrons from the emitter, characterized by involving a process of adhering a cathode electrode to an insulating substrate; a process of adhering a resistance layer to the cathode conductor; a process of forming a carbon layer by coating the resistance layer with a paste containing at least one of carbon nanotube, fullerene, nanoparticle, nanocapsule and carbon nanohorn; a process of adhering the paste-form carbon layer with a porous sheet material and drying to integrate the

carbon layer and the sheet; a process of forming an emitter by peeling the sheet material from the carbon layer then firing the carbon layer; and a process of forming a gate electrode at a position away from the emitter. Here, the porous sheet material is, e.g., paper, fabric or ceramic sheet.

[0013]

Also, according to the present invention a method is provided for the manufacture of an electron emission source by placing an emitter between a cathode conductor and a gate electrode then applying a voltage between the above cathode electrode and gate electrode to emit electrons from the emitter, characterized by involving a process of adhering a cathode electrode to an insulating substrate; a process of forming a carbon layer by coating the cathode electrode with a dispersion containing at least one of carbon nanotube, fullerene, nanoparticle, nanocapsule and carbon nanohorn; a process of drying the carbon layer; a process of forming an emitter by adhering an pressure-sensitive adhesive tape to the dried carbon layer then peeling the pressure-sensitive adhesive tape; and a process of forming a gate electrode at a position away from the emitter.

[0014]

Also, according to the present invention a method is provided for the manufacture of an electron emission source by placing an emitter between a cathode conductor and a gate electrode then applying a voltage between the above cathode electrode and gate electrode to emit electrons from the emitter, characterized by involving a process of adhering a cathode electrode to an insulating substrate; a process of adhering a resistance layer to the cathode electrode; a process of forming a carbon layer by coating the resistance layer with a dispersion containing at least one of carbon nanotube, fullerene, nanoparticle, nanocapsule and carbon nanohorn; a process of drying the carbon layer; a process of forming an emitter by adhering a pressure-sensitive tape to the dried carbon layer then peeling the pressure-sensitive adhesive tape; and a process of forming a gate electrode at a position away from the emitter.

[0015]

Also, according to the present invention an electron emission source is provided that is formed by placing an emitter between a cathode conductor and a gate electrode then applying a voltage between the above cathode electrode and gate electrode to emit electrons from the emitter, wherein the emitter is formed by coating the cathode electrode, directly or via a resistance layer, with a carbon material containing at least one of carbon nanotube, fullerene, nanoparticle, nanocapsule and carbon nanohorn, integrating the carbon material with a porous

sheet material or a pressure-sensitive adhesive tape, followed by peeling the porous sheet material or the pressure-sensitive adhesive tape to remove the surface of the carbon material.

[0016]

Also, according to the present invention a fluorescent display device is provided that is formed by placing an electron emission source and an anode electrode coated with a phosphor in a sealed vacuum container and colliding the electrons from the electron emission source with the phosphor to generate an emission display, characterized by using the electron emission source described above, as the electron emission source.

[0017]

PRACTICAL EMBODIMENTS OF THE INVENTION

Next, using drawings, the practical embodiments of the present invention are explained. In each drawing, the same parts are given the same symbols. Figure 1-6 are lateral cross-sectional diagrams for explaining a method for the manufacture of an electron emission source of the first embodiment of the present invention.

[0018]

First, in Figure 1, on an insulating substrate (101) of borosilicate glass, etc., a cathode conductor (102) is adhered in the form of a film of about 5 μm in thickness by screen printing of a silver paste then firing. Next, as shown in Figure 2, a paste of carbon material containing carbon nanotube is coated on the cathode conductor (102) by screen printing to form a carbon nanotube-containing carbon layer (201) of about 10 μm in thickness. For the carbon nanotube-containing paste material, a dispersion obtained by dispersing a carbon material containing carbon nanotube obtained by arc discharge method in a solution of ethyl cellulose in terpineol by ultrasound, etc. can be used.

[0019]

Next, as shown in Figure 3, before drying the carbon layer (201) in the paste form, a sheet material having a number of through holes, e.g., paper (301) is laid to make its one side in contact with the carbon layer to mount the paper (301) on the carbon layer (201) with adhesion to the surface of the carbon layer (201). By doing this, from one side of the paper (301), the carbon material such carbon nanotube, etc. enters together with the paste solution into the through holes of the paper (301). At this point, gas such as air, etc. passes through the through holes and stripped from the other side (back side), thus the entering of the carbon material into the through holes of paper (301) is facilitated.

[0020]

Then, the carbon layer (201) is dried in air at about 100°C for about 10 min, resulting in integration of the carbon layer (201) and the paper (301). Now, by peeling the paper (301) upward, the surface part of the carbon layer (201) is peeled off together with the paper (301), thus the carbon layer (201) is peeled from the middle part in the thickness direction and also the carbon nanotube included within the carbon layer (201) is exposed and oriented in vertical or near vertical direction to the substrate (101).

[0021]

Next, as shown in Figure 4, an emitter (401) is formed by firing at about 500°C for about 15 min in air with removal of organic components. By doing this, a cathode substrate (402) is formed. At this point, the organic components in the paste are decomposed and removed as gases without any changes in the shape of the carbon layer (301), thus carbon nanotube shape is retained with formation of a large number of carbon nanotubes with exposed tips oriented in vertical or near vertical direction to the substrate (101).

[0022]

Next, as shown in Figure 5, on a transfer molding release substrate (503) from a polypropylene layer (502) formed on a metal plate (e.g., SUS), a gate electrode (504) is formed by screen printing of a silver paste of about 5 μm in thickness and drying. Next, on the gate electrode (504), a glass insulating paste is screen printed to a thickness of about 40 μm and dried to form an insulating rib (505). By doing this, the rib gate electrode (506) is completed. Then, on the insulating rib (505), an acrylic pressure-sensitive adhesive layer (507) is printed. Next, as shown in Figure 6, transfer with position matching with the cathode substrate (402) for placing the gate electrode in the recessed part between the emitters (401) and firing in air at about 560°C for about 15 min complete a field emission type electron emission source.

[0023]

With installation of the thus obtained electron emission source in a sealed vacuum container and applying an operating voltage between the cathode conductor (102) and the gate electrode (504), electrons can be emitted from the emitter (401). Since, in the emitter (401), a large number of carbon nanotubes are exposed and oriented in vertical or near vertical direction to the insulating substrate (101) in a high density, electron emission occurs even at low operating voltage, and the electron emission occurs in a large quantity. Even when the components included in the solvents used for pastes remain on the surface of the carbon layer (201), they are

removed together with the paper (301) peeled, resulting in exposure of the carbon nanotubes, making highly efficient electron emission even at low operating voltage possible.

[0024]

Figure 7 shows a lateral cross-sectional diagram for explaining a method for the manufacture of an electron emission source in the second practical embodiment of the present invention. The difference between the first and second practical embodiments is in that while the first practical embodiment involves adhesion of the cathode conductor (102) to the insulating substrate (101) and direct adhesion of the emitter (401) to the cathode conductor (102), the second embodiment involves adhesion of the cathode conductor (102) to the insulating substrate (101), adhesion of the resistance layer (701) to the cathode conductor (102) and adhesion of the emitter (401) to the resistance layer (701). Otherwise, they are similar. The installation of the resistance layer (701) between the cathode conductor (102) and the emitter (401) enables the electron emission stabilization and prevention of over current formation when shorting of the gate electrode (504) and emitter (401) occurs.

[0025]

Next, the third embodiment of the present invention is explained. Figures 8-10 show lateral cross-sectional diagrams for explaining a method for the manufacture of an electron emission source of the third embodiment. First, a carbon material containing carbon nanotube formed by arc discharge method is pulverized using a pulverizer, dispersed well in a medium such as acetone using ultrasound, allowed to stand, and about upper half of the dispersion is recovered.

[0026]

On the other hand, as shown in Figure 8, on an insulating substrate (101) of borosilicate glass, etc., a cathode conductor (102) of about 5 μm in film thickness is adhered by screen printing of a silver paste and firing. Next, a mask (801) having openings (802) in a shape corresponding to the cathode conductor (102) pattern is positioned on the insulating substrate (101) with the openings (802) matching the cathode conductor (102) and placed in a container (not shown).

[0027]

Next, the carbon material dispersion recovered as described above is sprayed from the top of the mask (801) to the substrate placed in the container, allowed to dry naturally, freed from the mask (801) to form a laminate of the insulating substrate (101), the cathode conductor (102),

and carbon layer (904) formed in the same pattern as the cathode conductor (102). Here, the carbon layer (904) comprises a lower layer portion with high content of high-density material (metal catalyst used in forming carbon nanotube by arc discharge method), middle layer portion (902) with high content of monolayer carbon nanotube and the upper layer portion (903) with high content of low-density material (fullerene, etc.)

[0028]

Next, as shown in Figure 10, a pressure-sensitive adhesive tape (1001) that is a pressure-sensitive adhesive containing sheet material is adhered to the upper surface of the carbon layer (904) with integration of the carbon layer (904) and the pressure-sensitive adhesive tape (1001), then by peeling the pressure-sensitive adhesive tape (1001), the upper part (903) covering the top portion of the carbon layer (904) is peeled off together with the pressure-sensitive adhesive tape (1001), resulting in formation of the emitter (1002). By doing this, a cathode substrate (1003) is formed, and in the emitter (1002), the tip portion of the carbon nanotube included in the middle portion (902) is exposed. Then, similar to the first embodiment, a rib gate electrode is formed in the recessed area between the emitters (1002) to complete an electron emission source.

[0029]

Also, in the third practical embodiment, an electron emission source can be prepared with ready emission of electrons at low operating voltage in large quantities, i.e., providing an electron emission source with markedly improved field electron emission characteristics becomes possible. Also, even when unnecessary components included in the dispersion remain on the upper surface of the carbon layer (904), they are removed together with the pressure-sensitive adhesive tape (1001), thus the carbon nanotubes are exposed, making highly efficient electron emission at low operating voltage possible.

[0030]

In the third practical embodiment, the cathode conductor (102) is formed on the insulating substrate (101) then the emitter (1002) is formed directly on the cathode conductor (102). However, similar to the second practical embodiment, by including a process of adhering the cathode conductor (102) to the insulating substrate (101), a process of adhering a resistance layer to the cathode conductor (102) and a process of adhering the emitter (1002) to the resistance layer, electron emission stabilization and prevention of over current formation in shorting of the gate electrode and the emitter (1002) are possible.

[0031]

In each practical embodiment described above, the gate electrode is rib gate electrode, while gate electrodes of other structure such as mesh gate electrode, etc. are also possible. Also, while carbon nanotube-containing carbon material is used for emitter material with the carbon nanotube exposed at the emitter surface, carbon material containing fullerene, nanoparticle, nanocapsule or carbon nanohorn can also be used with exposure on the emitter surface. Namely, the emitter (301) material may be carbon materials containing at least one of monolayer or multilayer of carbon nanotube, fullerene, nanoparticle, nanocapsule and carbon nanohorn.

[0032]

Next, a fluorescent display device is formed using the electron emission sources described above. Figure 11 is a side view of a portion of a fluorescent display device of the practical embodiment of the present invention, illustrating an example of the fluorescent display device using the electron emission source prepared according to the first practical embodiment described above. In Figure 11, the fluorescent display device comprises the insulating substrate (101) that is the back side substrate from a borosilicate glass, the insulating substrate (1101) that is a transparent front substrate from a borosilicate glass, the seal glass (1104) that seals the edges of the insulating substrates (101, 1101) and a sealed vacuum container with vacuum interior.

[0033]

Also, as described above, the inner surface of the insulating substrate (101) is laminated with the cathode conductor (102) and the emitter (401) continuously formed to the cathode conductor (102). On the inner surface of the insulating substrate (101) is adhered the rib gate electrode (506) comprising the gate electrode (504) and the insulating rib (505) in the recessed area between the emitters (401). On the other hand, on the inner surface of the insulating substrate (1101) are installed the anode electrode (1102) and the phosphor (1103) coated on the anode electrode (1102) by lamination.

[0034]

In the case of fluorescent display devices for display of letters and graphics, the cathode conductor (102), the anode electrode (1102) and the gate electrode (504) are formed each in a matrix form or in a mixed form of solid and matrix forms, as needed. Such electrode patterns can be chosen as needed even in the fluorescent display devices using pixel emission elements for large displays.

[0035]

In the fluorescent display devices of the constitution described above, by feeding an operating signal of certain voltage to the cathode conductor (102), the gate electrode (504) and the anode electrode (1102), the phosphor (1103) emits light, and according to the each electrode pattern and operating signal, letters and graphics are displayed or display can be obtained by emission elements. In doing this, field concentrates at the carbon nanotube, etc. exposed on the surface of the emitter (401), thus emission displays of high quality and high brightness can be obtained at low operating voltage.

[0036]

As described above, in methods for the manufacture of an electron emission source by installing an emitter between a cathode conductor and a gate electrode with application of a voltage between the cathode conductor and the gate electrode to emit electrons from the emitter, the methods for the manufacture of electron emission sources in the practical embodiments of the present invention involves a process of adhering the cathode conductor (102) to the insulating substrate (101), a process of forming the carbon layer (201) by coating a paste containing at least one of carbon nanotube, fullerene, nanoparticle, nanocapsule and carbon nanohorn to the cathode conductor (102), a process of adhering the carbon layer (201) in a paste form to a porous sheet material such as paper (301), etc. and drying to integrate the carbon layer (201) and the sheet material, a process of peeling the sheet material form the carbon layer (201) then firing the carbon layer to form the emitter (401) and a process of forming the rib or mesh gate electrode (506) away from the emitter (401) on the cathode substrate (402). By doing this, the solvent components, etc. coated on the surface of the carbon material are removed and also the electron emission material such as carbon nanotubes, etc. are exposed and oriented in vertical or near vertical direction to the insulating substrate (101), making easy concentration of field to the electron emission material. Thus, electron emission sources capable of highly efficient electron emission at low voltage can be prepared.

[0037]

In the manufacturing processes, a process of adhering the resistance layer (701) formed from RuO_2 based resistance material, etc. to the cathode conductor (102) may be added between the process of adhering the cathode conductor (102) and the process forming the emitter (401). Namely, a manufacturing method may involve a process of adhering the cathode conductor (102) to the insulating substrate (101), a process of adhering the resistance layer (701) to the cathode conductor (102), and a process of forming the emitter (401) by adhering at least one of carbon nanotube, fullerene, nanoparticle, nanocpasule and carbon nanohorn to the resistance layer (701).

By doing this, electron emission sources capable of highly efficient electron emission at low voltage as described above can be prepared with good electron emission stability and prevention of over current formation in shorting of the electrodes. The porous sheet materials described above may be, e.g., paper, fabrics, ceramic sheets, etc., having a large number of through holes.

[0038]

In methods for the manufacture of an electron emission source by installing an emitter between a cathode conductor and a gate electrode with application of a voltage between the cathode conductor and the gate electrode to emit electrons from the emitter, the methods for the manufacture of electron emission sources in the practical embodiments of the present invention involve a process of adhering the cathode conductor (102) to the insulating substrate (101), a process of forming the carbon layer (904) by coating a dispersion containing at least one carbon material from carbon nanotube, fullerene, nanoparticle, nanocapsule and carbon nanohorn to the cathode conductor (102), a process of drying the carbon layer (904), a process of adhering the pressure-sensitive adhesive tape (1001) to the dried carbon layer (904) then peeling the pressure-sensitive adhesive tape (1001) together with the top portion of the carbon layer (904) to form the emitter (1002), and a process of forming a gate electrode at a position away from the emitter (1002). By doing this, the solvent components, etc. coated on the surface of the carbon material such as carbon nanotube, etc. included in the emitter (1002) are removed and also the electron emission material such as carbon nanotubes, etc. are exposed and oriented in vertical or near vertical direction to the insulating substrate (101), making easy concentration of field to the electron emission material. Thus, electron emission sources capable of highly efficient electron emission at low voltage can be prepared.

[0039]

As described above, in the manufacturing processes, a process of adhering the resistance layer formed from RuO_2 based resistance material, etc. to the cathode conductor (102) may be added between the process of adhering the cathode conductor (102) and the process forming the emitter (1002). Namely, a manufacturing method may involve a process of adhering the cathode conductor (102) to the insulating substrate (101), a process of adhering the resistance layer to the cathode conductor (102), and a process of forming the emitter by adhering at least one of carbon nanotube, fullerene, nanoparticle, nanocapsule and carbon nanohorn to the resistance layer. By doing this, electron emission sources capable of highly efficient electron emission at low voltage as described above can be prepared with good electron emission stability and prevention of over current formation in shorting of the electrodes.

[0040]

In methods for the manufacture of an electron emission source by installing an emitter between a cathode conductor and a gate electrode with application of a voltage between the cathode conductor and the gate electrode to emit electrons from the emitter, according to the practical embodiments of the present invention, the emitters (401, 1002) are formed by adhering a carbon material containing at least one of carbon nanotube, fullerene, nanoparticle, nanocapsule and carbon nanohorn directly or via the resistance layer (701) to the cathode conductor (102), followed by integrating the carbon material with paper (301) or pressure-sensitive adhesive tape (1001) then peeling the paper (301) or the pressure-sensitive adhesive tape (1001) to remove the top portion of the carbon material. Thus, electric field is easily concentrated to the carbon nanotube, etc. exposed over the surface of the emitter (401, 1002), and emission display of high brightness and high quality can be obtained at a low operating voltage.

[0041]

Although examples of electron emission sources of spatial structure with the gate electrode (504) placed on the cathode conductor (102) are explained in the practical embodiments, planar electron emission sources having both the cathode conductor and gate electrode placed on the same plane on the insulating substrate are also possible.

[0042]

APPLICATION EXAMPLE

Figure 12 is a lateral cross-sectional diagram illustrating a device for evaluating the characteristics of an electron emission source of the present invention, and Figure 13 and 14 show such characteristics. The electron emission source used in Figure 12 is the one prepared by the method of the third practical embodiment. On the inner surface of the insulating back substrate (101) constituting the vacuum outer part (1203) is adhered the cathode conductor (102) and the emitter (1002). On the inner surface of the insulating substrate (1101) is adhered the anode electrode (1102) facing against the emitter (1002). Between the cathode conductor (102) and the anode electrode (1102) the d.c. source (1201) and the ammeter (1202) are connected serially. The distance between the cathode conductor (102) and the anode electrode (1102) is 100 μm, and the cathode conductor (102) and the emitter (1002) are circular with diameter 1 mm.

[0043]

With the (I-V) characteristics of the current I between the emitter (1002) and the anode electrode (1102) and the voltage E applied between the cathode conductor (102) and the anode electrode (1102) as shown in Figure 3, in the one with the pressure-sensitive adhesive tape peeling treatment (treated), current flow starts at about 300 V and has lower threshold value of electron emission with higher amount of electrons emitted than the one without the treatment (untreated). The treated one also has higher reproducibility.

[0044]

As shown by the F-N (Fowler-Nordheim) plot in Figure 14, both the treated one (treated) and untreated one (untreated) are straight lines with negative slope, indicating electric field electron emission. The treated one and untreated one have identical slope of the characteristics, while the treated one has the characteristics formed by parallel shift to the right of the characteristics of the untreated one. This indicates that there is no enhancement of field electron emission characteristics of each carbon nanotube in the emitter (1002), while the number of carbon nanotubes contributing to the field electron emission is increased.

[0045]

EFFECTS OF THE INVENTION

According to the present invention, a method for the manufacture of electron emission sources showing high efficiency at low voltage can be provided. By this, electron emission sources with excellent electron emission characteristics can be provided. Also, fluorescent display devices that can be operated at low voltage with high brightness and quality can be provided.

BRIEF EXPLANATION OF FIGURES

Figure 1 is a lateral cross-sectional diagram for explaining a method for the manufacture of an electron emission source of the first practical embodiment of the present invention and also illustrates the process of adhering the cathode conductor to the insulating substrate.

Figure 2 is a lateral cross-sectional diagram for explaining the method for the manufacture of the electron emission source of the first practical embodiment of the present invention and illustrates the process of forming a carbon layer.

Figure 3 is a lateral cross-sectional diagram for explaining the method for the manufacture of the electron emission source of the first practical embodiment of the present invention and illustrates the process of integrating the carbon layer and the sheet material.

Figure 4 is a lateral cross-sectional diagram for explaining the method for the manufacture of the electron emission source of the first practical embodiment of the present invention and illustrates the process of forming the emitter.

Figure 5 is a lateral cross-sectional diagram for explaining the method for the manufacture of the electron emission source of the first practical embodiment of the present invention and illustrates the process of forming the gate electrode.

Figure 6 is a lateral cross-sectional diagram for explaining the method for the manufacture of the electron emission source of the first practical embodiment of the present invention and illustrates the process of forming the gate electrode.

Figure 7 is a lateral cross-sectional diagram for explaining the method for the manufacture of the electron emission source of the second practical embodiment of the present invention.

Figure 8 is a lateral cross-sectional diagram for explaining the method for the manufacture of the electron emission source of the third practical embodiment of the present invention.

Figure 9 is a lateral cross-sectional diagram for explaining the method for the manufacture of the electron emission source of the third practical embodiment of the present invention and illustrates the process of forming the carbon layer.

Figure 10 is a lateral cross-sectional diagram for explaining the method for the manufacture of the electron emission source of the third practical embodiment of the present invention and illustrates the process of forming the emitter.

Figure 11 is a lateral view of a cut of the fluorescent display device of the practical embodiments of the present invention.

Figure 12 is a diagram illustrating a device for measurement of the characteristics of the electron emission source of the Application Example of the present invention.

Figure 13 is an I-V characteristic diagram of the electron emission source of the Application Example of the present invention.

Figure 14 is an F-N plot of the electron emission source of the Application Example of the present invention.

EXPLANATION OF SYMBOLS

102	Cathode conductor
201, 904	Carbon layer
301	Paper as a sheet material
401, 1002	Emitter
402	Cathode substrate
504	Gate electrode

505 Insulating rib
506 Rib gate electrode
701 Resistance layer
801 Mask
1001 Pressure-sensitive adhesive tape
1101 Insulating substrate that is a front substrate constituting the sealed vacuum container
1102 Anode electrode
1103 Phosphor

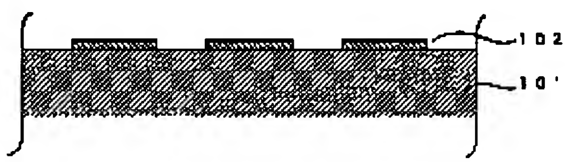


Figure 1

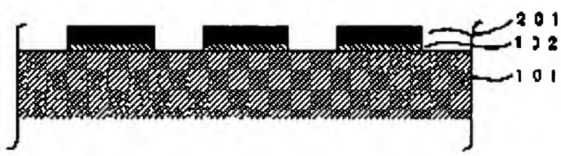
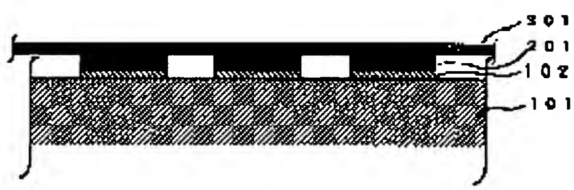


Figure 2



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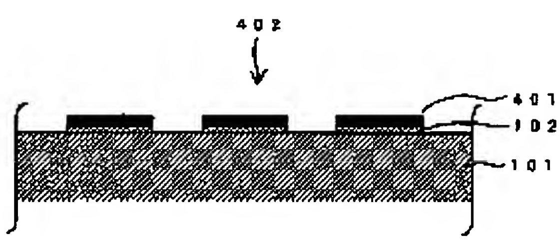

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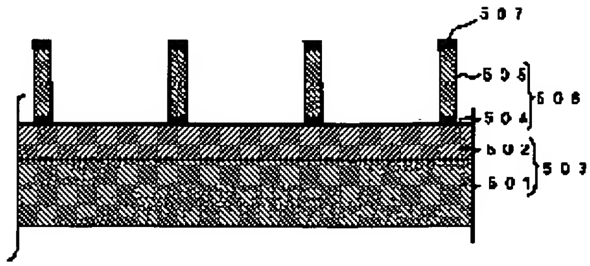

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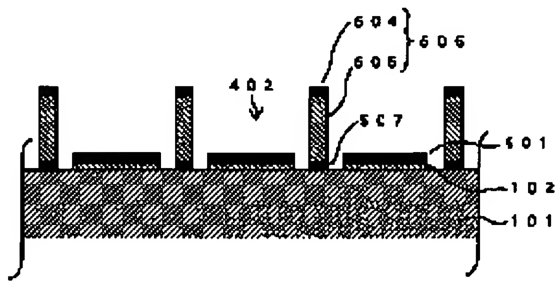
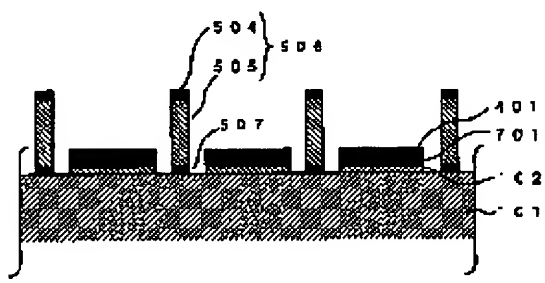


Figure 6



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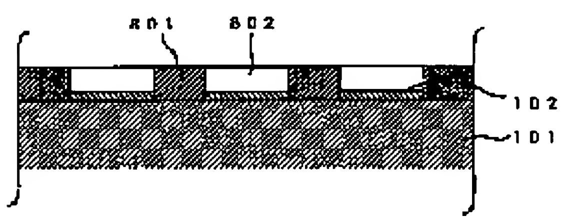

Figure 8

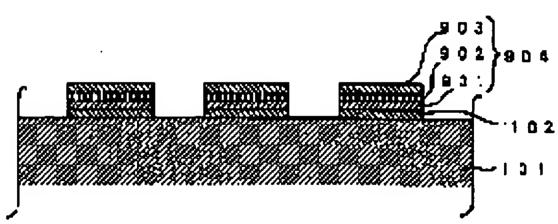

Figure 9

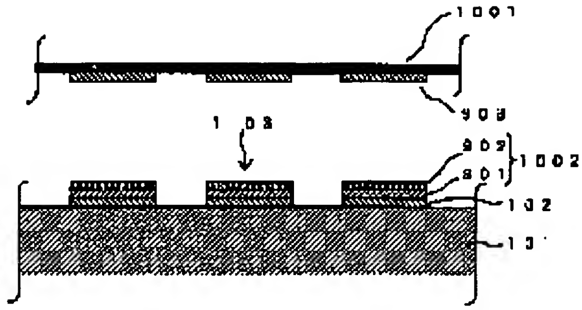

Figure 10

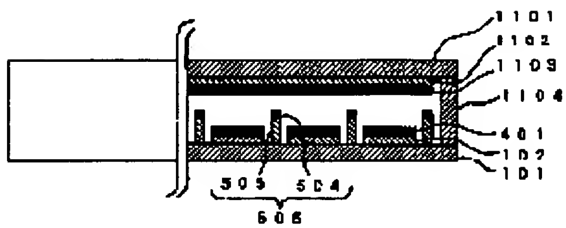

Figure 11

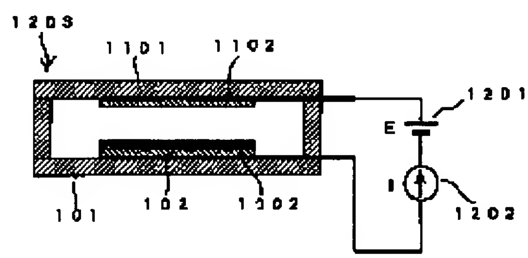

Figure 12

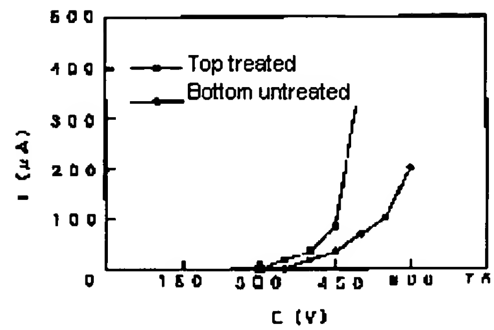

Figure 13

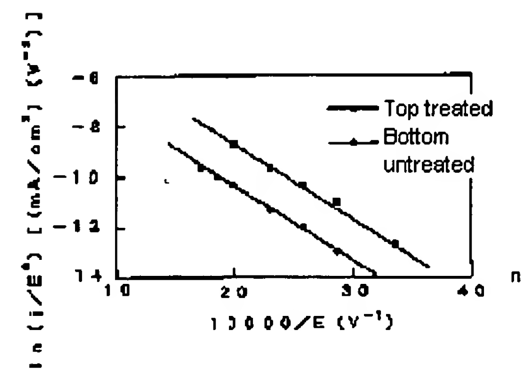

Figure 14

Language Services Unit
Phoenix Translations
August 17, 2001